



Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

Trends in management of odontoid fractures 2010–2021

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ARTICLE INFO

Keywords:

Odontoid fracture
Anterior screw fixation
Posterior fusion
Pearlriver
Database

ABSTRACT

Background Context: Odontoid fractures are relatively common. However, the literature is unclear how these fractures are best managed in many scenarios. As such, care is varied and poorly characterized.

Purpose: To investigate the trends and predictive factors of surgical versus nonsurgical treatment and anterior versus posterior stabilization of odontoid fractures.

Study Design/Setting: Retrospective database cohort study.

Patient Sample: Adult patients with odontoid fractures between 2010 and 2021.

Outcome Measures: Yearly trends and predictors of odontoid fracture management.

Methods: Adult patients with odontoid fractures were abstracted from the large, national, administrative M161Ortho Pearlriver dataset. For operative versus nonoperative care of odontoid fractures, yearly rates were determined (since 2016 based on coding limitations). For anterior versus posterior stabilization, yearly rates were determined (2010–2021). Univariate and multivariable analyses were performed for both sets of comparisons.

Results: For assessment of nonsurgical versus surgical management from 2016 to 2021, a total of 42,754 patients with odontoid fracture were identified, of which surgical intervention was done for 7.9%. Predictive factors of surgical intervention included being managed by a neurosurgeon (OR:1.29), being from Midwest United States (OR:1.35 relative to West), male sex (OR:1.20), and decreasing age (OR: 0.82 per decade) ($p < .001$ for each). Of those undergoing surgical intervention, 33.6% had anterior surgery while 66.4% had posterior surgery (anterior surgery decreased from 36.4% in 2010 to 27.2% in 2021, $p < .001$). Predictive factors of undergoing anterior versus posterior approach include having a neurosurgeon surgeon (OR:1.98), being from the Southern (OR:1.61 relative to Northeast), and having Medicare insurance (OR: 1.31) ($p < .001$ for each).

Conclusions: The overall rate of surgery for odontoid fractures has remained similar over the past years. Of those undergoing surgery, less are being done from anterior. While these decisions were predicted by some clinical factors, both also correlated with nonclinical factors suggesting room for more consistent algorithms.

Introduction

Odontoid fractures are common fractures [1] that are increasing in frequency [2,3]. These can be managed nonsurgical or surgically using either posterior or anterior approaches [4]. The literature is mixed with regard to best treatments, and thus trends and drivers of such decisions are poorly defined.

The decision whether to manage these fractures surgically or nonsurgically has remained challenging, with each treatment having their own advantages and disadvantages [4–6]. Surgically managed patients

are at decreased rates of nonunion, however they are at risk of operative complications and prolonged length of stay [4,5,7,8]. Prior systematic reviews and meta-analysis have considered patient selection for surgical versus nonsurgical management [4,6], however, there has been a lack of quality evidence to build guidelines. While some reviews have suggested increasing rates of operative treatment [3,9,10] that has not been shown by others [11,12].

When surgery is pursued, this can be done from anterior or posterior approaches. Again, each is with distinct advantages and disadvantages [13]. While Subach et al. [14] reported acceptable outcomes using an

FDA device/drug status: Not applicable.

Author disclosures: **MJG:** Nothing to disclose. **SSJ:** Nothing to disclose. **AES:** Nothing to disclose. **JM:** Nothing to disclose. **WD:** Nothing to disclose. **PPR:** Nothing to disclose. **JNG:** Board of Directors: NASSJ (D).

Given his role as Editor in Chief, Jonathan Grauer, MD had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to Tobias Mattei, MD.

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<https://doi.org/10.1016/j.xnsj.2024.100553>

Received 7 August 2024; Received in revised form 27 August 2024; Accepted 27 August 2024

Available online 1 September 2024

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anterior approach, others have reported an increased risks and negative outcomes, especially when compared to posterior fusions [15–20]. Over time, some have found that the anterior approach is decreasing in popularity [3].

Overall, most prior literature regarding odontoid fracture management has been limited by small sized cohorts and variable inclusion/exclusion criteria. With prior literature being mixed whether surgical management was growing in popularity for management, it was hypothesized that the annual rate of surgical management has been relatively flat or seen a slight increase. However, given recent literature suggesting that posterior fusion may have superior outcomes, it was hypothesized that surgical management may be trending towards the posterior approach.

The current study thus leveraged a large, national, multi-insurance database to define treatment trends and determine if clinical and/or nonclinical factors predicted which management and surgical approach were utilized.

Methods

Patient sample

The current study made use of data from the 2010–Q1 2022 M161Ortho PearlDiver Mariner Patient Claims Database (PearlDiver Technologies, Colorado Springs, CO, USA). This national administrative database makes use of insurance claims data from over 161 million patients in the United States. Use of this dataset has been well-established in spine studies [21–25]. Our Investigate Review Board (IRB) has deemed that any studies using making use of this database to be exempt from review due to data being output in de-identified and aggregated form.

Odontoid Fractures were identified with International Classification of Diseases (ICD)-10 codes. It was only possible to use ICD coding to identify odontoid fractures from October 2015 onwards, subsequent to the introduction of ICD-10 coding (prior to that ICD-9 coding was more general grouped different types of C2 fractures).

Surgical management of odontoid fractures was able to be identified through the entire years of the data. Anterior screw fixation was identified based on CPT codes 22318 and 22319. Posterior C1-C2 fusion was identified based on CPT code 22595. Surgeries that went up to the occiput or down to C3 were included, however all other concurrent spinal surgery was excluded from the cohort.

Patients were excluded from the cohort if they were younger than eighteen years of age, or if there was concurrent diagnosis of infection or neoplasm (in order to isolate traumatic fractures). Patient characteristics were obtained from the dataset. Clinical characteristics included: age, sex, Elixhauser comorbidity Index (ECI), and osteoporosis. Nonclinical characteristics included: geographic region of country the surgery was performed (South, Midwest, Northeast, or West), insurance plan (Commercial, Medicare, or Medicaid), and surgeon subspecialty (neurosurgeon vs. orthopedic surgeon). For nonsurgical management, only neurosurgeons and orthopedic surgeons were included.

Data analyses

For 2016 through 2021, the incidence of odontoid fractures per year was defined and percent undergoing anterior or posterior fixation defined. Chi-square tests were used to compare percentage of nonsurgical versus surgical management from 2016 to 2021.

For nonsurgical versus surgical management of odontoid fractures, univariate chi-square tests were used for categorical variables (sex, region, diagnosis of osteoporosis, region, plan, and surgeon type) and *t* test were used for continuous variables (age, ECI). Multivariable logistical regression was then performed.

For 2010 through 2021, surgical cases were assessed as being performed from posterior relative to anterior over the years. Chi-square

Trend of Surgical Versus Non-Surgical Management for Odontoid Fractures

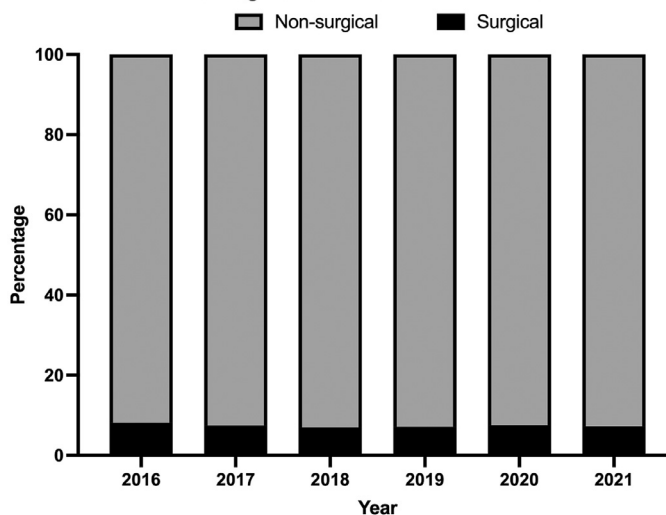


Fig. 1. Trends in nonsurgical versus surgical management of odontoid fractures from 2016 to 2021. There was not a significant change in surgical versus non-surgical management over time ($p=.11$).

tests were used to compare percentage of posterior versus anterior surgeries from 2010 to 2021.

For posterior versus anterior surgery management of odontoid fractures, univariate chi-square tests were used for categorical variables (sex, region, diagnosis of osteoporosis, region, plan, extension to occiput, and surgeon type) and *t* test were used for continuous variables (age, ECI). Multivariable logistical regression was then performed.

Statistical analysis was performed using R suite built into the PearlDiver Patient Claims Database (PearlDiver Technologies, Colorado Springs, CO, USA) for analysis of patient characteristics and multivariable analysis of predictive factors. All figures and the year-to-year statistical analysis was performed with Graphpad Prism 10 (GraphPad Software, San Diego, CA). Significance was set at $p < .05$.

Results

Surgical versus nonsurgical management

Trends in management

From 2016 to 2021, there were a total of 34,748 patients identified with odontoid fractures (Table 1). Of these, nonsurgical management was pursued for the significant majority 32,016 (92.7%) and surgery was pursued for 2,732 (7.3%).

The year-by-year trends in operative versus nonoperative management are shown in Fig. 1. Proportionally, there was not a significant change in surgical versus nonsurgical management from 2016 to 2021 ($p=.11$). In 2016, 8.1% of fractures were managed surgically, and 91.9% of fractures were managed nonsurgically. In 2021, 7.2% of fractures were managed surgically, and 92.8% of fractures were managed nonsurgically.

Predictive factors

By univariate analysis, surgically managed patients tended to be younger (67.2 vs. 73.1 years of age), were more likely to be male (50.2% vs. 45.4%), had a lower comorbidity burden (5.9 vs. 7.0 ECI), and were less likely to have a diagnosis of osteoporosis (28.5% vs. 30.8%), were from different parts of the country, were of different insurance distribution, and less likely to be pursued by neurosurgeons (79.5% vs. 87.3%) ($p < .001$ for each, Table 1).

Multivariable analysis results are shown in Table 1. Independent clinical predictors of surgical management were as follows (in descend-

Table 1
Patient characteristics of all odontoid fractures and odds of undergoing surgical management compared to nonsurgical management.

	Univariate analysis			Multivariate analysis	
	Nonsurgical management	Surgical management	p-value	Odds ratio (95% CI)	p-value
Total	32,016	N = 5,165			
Age (SD)	73.1 (12.6)	67.2 (13.7)	<.001	0.82 Per Decade (0.80–0.85)	<.001
Sex			<.001		
Female	17,471 (54.6%)	2,572 (49.8%)		REF	REF
Male	14,545 (45.4%)	2,593 (50.2%)		1.20 (1.10–1.32)	<.001
ECI	7.0 (4.2)	5.9 (4.0)	<.001	1.01 (1.00–1.15)	.177
Osteoporosis	9,857 (30.8%)	1,471 (28.5%)	<.001	1.07 (0.96–1.18)	.245
Region			<.001		
West	5,459 (17.1%)	672 (13.0%)		REF	REF
South	12,070 (37.7%)	1,983 (38.4%)		1.20 (1.04–1.38)	.011
Midwest	8,503 (26.6%)	1,549 (30.0%)		1.35 (1.17–1.57)	<.001
Northeast	5,784 (18.1%)	941 (18.2%)		1.08 (0.92–1.27)	.0334
Plan			<.001		
Commercial	14,566 (45.5%)	2,787 (54.0%)		REF	REF
Medicare	11,509 (35.9%)	1,889 (36.6%)		0.90 (0.82–0.99)	.040
Medicaid	1,295 (4.0%)	236 (4.5%)		0.94 (0.76–1.15)	.562
Surgeon Type			<.001		
Orthopaedics	912 (12.7%)	912 (17.7%)		REF	REF
Neurosurgery	6,258 (87.3%)	4,107 (79.5%)		1.29 (1.14–1.46)	<.001

Table 2
Patient characteristics of those who underwent fixation for odontoid fractures and odds of undergoing anterior fixation compared to posterior fixation.

	Univariate analysis		Multivariate analysis		
	Posterior fixation	Anterior fixation	p-value	Odds ratio (95% CI)	p-value
Total	N = 3,557 (66.4%)	N = 1,800 (33.6%)			
Age (SD)	66.9 (13.6)	67.6 (13.9)	.646	1.01 per decade (0.96–1.06)	.700
Sex			.815		
Male	1,794 (50.4%)	901 (50.1%)		REF	REF
Female	1,763 (49.6%)	899 (49.9%)		0.96 (0.85–1.09)	.541
ECI	5.95 (4.04)	5.62 (4.01)	.004	0.97 per point (0.96–0.99)	.001
Osteoporosis	997 (28.0%)	528 (29.3%)	.333	1.08 (0.94–1.25)	.275
Region			<.001		
Northeast	731 (20.6%)	240 (13.3%)		REF	REF
South	1,294 (36.4%)	764 (42.4%)		1.61 (1.35–1.93)	<.001
Midwest	1,068 (30.0%)	540 (30.0%)		1.44 (1.20–1.74)	<.001
West	449 (12.6%)	247 (13.7%)		1.55 (1.24–1.93)	<.001
Plan			<.001		
Commercial	1,985 (55.8%)	903 (50.2%)		REF	REF
Medicare	1,221 (34.3%)	740 (41.1%)		1.31 (1.15–1.49)	<.001
Medicaid	168 (4.7%)	79 (4.4%)		1.06 (0.79–1.42)	.222
Occiput	612 (17.2%)	-	-	-	-
Surgeon Type			<.001		
Orthopaedics	740 (20.8%)	202 (15.2%)		REF	REF
Neurosurgery	2,740 (77.0%)	1,527 (84.8%)		1.98 (1.67–2.36)	<.001

ing order): being male (OR: 1.20) and increasing age (OR: 1.12 per decade) (p < .001 for both). Independent nonclinical predictors of surgical management were as follows (in descending order): being in the Midwest or South (OR: 1.35 p < .001 and OR:0.011 p=.011, respectively relative to West) and having a neurosurgeon (OR: 1.29 p < .001), but less likely if Medicare (OR0.90 p=.04 relative to Commercial) (p < .001 for each, Table 1).

Surgical management anterior versus posterior

Trends in management

From 2010 to 2021, a total of 5,357 patients identified with odontoid fractures who had surgical management (Table 2). Amongst patients that received surgical management, a majority received posterior surgery (n = 3,557, 66.4%) and lesser received anterior surgery (n = 1,800, 33.6%).

The year-by-year trends in anterior versus posterior surgery are shown in Fig. 2. Proportionally, the number of surgeries performed from

anterior decreased from 2010 to 2021 (p < .0005). In 2010, 36.4% of the surgeries were done from anterior and 63.6% were done from posterior. In 2021, 26.2% of the surgeries were done from anterior and 73.8% were done from posterior.

Predictive factors

By univariate analysis, those who underwent anterior surgery was more likely to be performed for those who were of slightly lower comorbidity (4.01 vs. 4.04 ECI), were from different parts of the country, were of different insurance distribution, and more likely to be pursued by neurosurgeons (84.8% vs. 77.0%) (p < .001 for each other than ECI=0.004, Table 2).

Multivariate analysis results are shown in Table 2. Independent clinical predictors of receiving anterior surgery relative to posterior surgery was only lower ECI (OR: 0.96 per point increase, p=.001). Independent nonclinical predictors of anterior surgery were as follows (in descending order): having a neurosurgeon (OR: 1.98), geography (relative to

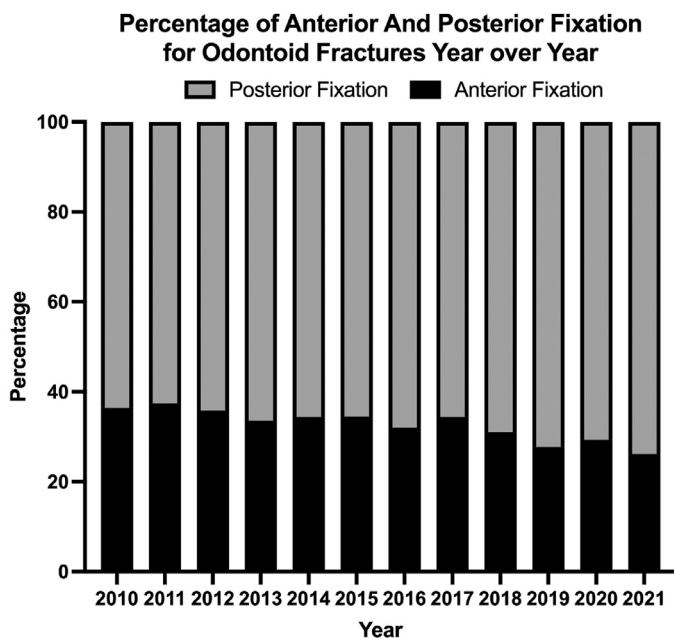


Fig. 2. Trends in surgical approach for odontoid fractures from 2010 to 2021. There is a significant, mild, decrease year over year in anterior fixation.

Northeast, South OR: 1.61, Midwest OR: 1.44, West OR: 1.55, and having Medicare (OR: 1.31 relative to Commercial) ($p < .001$ for each).

Discussion

Odontoid fractures are a common spinal injuries, making up 9%–18% of cervical fractures [26]. The present study investigated the trends over the last decade for how these fractures have been managed and factors that predisposed patients to be treated with versus without surgery and from anterior versus posterior.

The current study found that over 90% of odontoid fractures have been managed nonoperatively from 2016 to 2021. This trend was stable from year to year, with no significant difference. This finding is consistent with other literature [27,28] suggesting that nonsurgical management is more common than operative management. In 2008, the Cochrane Library performed a systemic review comparing outcomes between surgical versus nonsurgical management of odontoid fractures, and concluded that there was a lack of quality evidence at the time for which care approach leads to better outcomes [29]. One multi-center European study found excellent functional outcomes in patients being managed nonsurgically, regardless of degree of bony fusion, and suggested for patients that failed conservative management that surgical fixation was appropriate at a further date [30].

Factors associated with surgical management were then defined. In terms of clinical factors, surgical intervention was more likely for younger (OR: 0.82 per decade increase) male (OR 1.20) patients. This is consistent with prior literature, which suggests that surgeons may favor surgical management for younger patients in part due to their better bone health [31], while avoiding it in the older population due to their increasing comorbidities [32]. Male patients may have had higher energy injuries associated with more severe injuries and been more indicated for surgical intervention [33]. Interestingly ECI and osteoporosis were non found to be independent predictors of surgical intervention. These clinical factors indicate important patient factors that drive surgeon decision making for the management of these fractures.

Surgical management was also predicted by nonclinical factors such as geographic region (relative to West, South OR: 1.20, Midwest OR: 1.35), insurance (relative to Commercial, Medicare OR: 0.90, and sur-

geon type (relative to orthopedics, neurosurgery OR: 1.29). These non-clinical factors highlight the fact that there is lack of consensus and universally accepted algorithm-driven decisions. In a related way, variations have been associated with geographic region [34] and insurance [35] for other spine decisions for which variations in care exist. Notably, a systemic review recently suggested that postoperative outcomes spine surgery outcomes did not differ between orthopedic surgeons and neurosurgeons [36]. With region and surgeon type playing a role in management option, there's likely an institutional or training bias towards certain options that may be driving these findings overall.

The next set of analyses focused on the cohort of patient who underwent surgery and assessed what surgeries were done from anterior versus posterior approaches. Over the time period of the study, less surgeries were done from anterior (36.4% on 2010 down to 26.2% in 2021). Selection of anterior versus posterior approach is another area where prior literature is mixed. Anterior fixation has been associated with a shorter operating time [18,37] and increased motion retention [37]. The posterior approach is associated with a significantly higher rate of overall fusion comparatively [38]. However, the literature is mixed on outcomes of both techniques. While some studies state relatively similar outcomes between the 2 [39], others have found that the posterior approach has a significantly lower rate of reoperations and readmissions [18,37,38].

Surgical approach was associated with comorbidity burden with those of higher ECI being slightly more likely to receive the posterior approach as well (anterior OR: 0.96), potentially suggesting that some surgeons see it as more definitive procedure in this patient population. There were several nonclinical variables that were also significant for whether a patient was more likely to have surgery via anterior versus posterior approach, including geographic region (relative to Northeast, South OR: 1.61, Midwest OR: 1.44, West OR: 1.55), insurance plan (relative to commercial, Medicare OR: 1.31), and surgeon specialty (relative to orthopedics, neurosurgery 1.98). As with decision for nonsurgical versus surgical care, these nonclinical factors point to is lack of consensus and universally accepted algorithm-driven decisions. Prior literature has suggested these nonclinical factors, such as insurance or region, contribute significantly to the variation between nonsurgical versus surgical management for orthopedic procedures [40,41].

There are limitations to this study. As with any administrative database, the data is limited by the quality and granularity of the coded data. The greatest factor here is that the morphology of the fracture could not be assessed. Further, nonsurgical care could not be assessed prior to 2016 due to ICD-9 coding limitations. Further, patient clinical outcomes also could not be assessed. This included information such as radiographic information of the fractures which would affect their management options. Similarly, surgeon-related factors such as time since finished training were not available for analysis.

In summary, the present study showed that the overall rate of surgery for odontoid fractures has remained similar over the past years. Of those undergoing surgery, less are being done from anterior. While these decisions were predicted by some clinical factors, both also correlated with nonclinical factors suggesting room for more consistent algorithms. The nonclinical factors here suggest bias towards certain treatment options amongst different surgeons that could become more standardized going forward with improved guidelines. There's room for future studies to better characterize what factors should play a role in determining appropriate management for these patients for more consistent care, particularly for surgically managed odontoid fractures.

Institutional review board approval

Our Institutional review board has determined studies using the utilized database exempt from review.

Declaration of competing interest

Michael Gouzoulis received James G Hirsch Medical Student Fellowship from Yale University School of Medicine. Jonathan N Grauer is Editor-in-Chief of North American Spine Society Journal and a member of the North American Spine Society Board of Directors.

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